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THE ROLE OF THE U.S. GOVERNMENT TECHNICAL REPORT IN AERONAUTICS: AN EXPLORATORY STUDY

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National Aeronautics and Space Adminstration
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The purpose of the study is to explore the production, transfer, and use of scientific and technical information (STI) by aeronautical engineers and scientists for the purpose of determining the role of the U.S. government technical report in aeronautics. A secondary purpose is the creation of a knowledge base regarding the handling and use of STI by the same community. Elements of this study are: to determine the extent to which the purpose for which information is used and the information source selection is influenced; to determine the extent to which the selection of an information source is influenced by the factors of accessibility, expense, relevance, timeliness, and comprehensiveness; to identify the attitudes of aeronautical engineers and scientists toward information technology; to identify the attitudes toward scientific and technical libraries; to determine the extent to which there may be discontinuity between the Federal systems that handle STI and the aeronautical community to whom the STI is directed.

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INTRODUCTION

The aerospace industry continues to be the leading positive contributor to the United States (U.S.) balance of trade among all merchandise industries, including agriculture. In the face of increasing foreign competition, U.S. aerospace exports rose from $19.7 billion in 1986 to an estimated $21.4 billion in 1987. The 1986 U.S. aerospace trade surplus of $11.8 billion grew to a new high of approximately $13.7 billion in 1987.[1]

According to the U.S. Department of Commerce, the U.S. aerospace industry can look forward to the next five years with optimism. The structure of the industry will continue to change as increasing U.S. collaboration with foreign producers results in a more international manufacturing environment. The changing composition of the industry will foster an increasing flow of U.S. aerospace trade. At the same time, international industrial alliances will result in a more rapid diffusion of technology, increasing the pressure on the U.S. aerospace industry to push forward with new technological developments.[2]

The commercial aircraft industry is unique among manufacturing industries in that a government research organization, the National Advisory Committee on Aeronautics (NACA), which became the National Aeronautics and Space Administration (NASA) in 1958, has for many years conducted and funded research on airframe and propulsion technologies.[3]

In its wind tunnels and laboratories, the NACA conducted both basic and applied research, guided by committees made up of representatives of industry, the military services, and university aeronautical engineers and scientists. According to Shapley and Roy, a pattern of collaboration grew up which provided the technical basis for the success of the U.S. aviation industry.[4]

In Science: The Endless Frontier, Vannevar Bush proposed the creation of a National Research Foundation to formulate and implement federally funded research and development (R&D).[5] According to Shapley and Roy, the models that Bush invoked for the proposed foundation were the land-grant colleges and the NACA. Both models "offered science, applied science, technology, and a system for coupling knowledge with people who would use it in the field."[6] Mowery and Rosenberg also view the NACA as a model for government and industry cooperation in research and note that this model has been advocated for use in other industries.[7] Shapley and Roy further state that NASA's good record in coordinating industry and government research and technology (R&T), which is derived in part from its inheritance of the NACA tradition, has helped the U.S. aviation industry dominate the world's commercial aircraft market.[8] The Congressional Office of Technology Assessment (OTA) states that "although it is not possible to isolate the civilian return on Federal aviation R&D, the dramatic expansion of the airline and aircraft industries in

the U.S. after World War II is a clear indication of the benefits of this unique Federal sector policy."[9] According to David Mowery, the "total factor productivity in the commercial aviation industry has grown more rapidly than in virtually any other U.S. industry during the postwar period,"[10] a claim that is disputed by Terleckyj.[11,12]

What factors are responsible for the American aviation industry becoming a star performer in the American economy? Mowery and Rosenberg state that the success can be attributed to the transfer of innovations in other industries to aviation, such as metallurgy and electronics; government supported research in civil aviation; and military procurement and research support.[13] According to the Keyworth report, <u>National Aeronautical R&D Goals: Technology For America's Future</u>, the principal reasons for success include technical superiority; efficient and effective manufacturing, production, and marketing techniques; and the competitive cost of U.S. aircraft and associated parts. The report also acknowledges that technical superiority is due in part to the R&T data generated by NASA, the Department of Defense (DOD), the aviation industry, and by university aeronautical engineers and scientists.[14]

The R&T data are transmitted to "people who use it in the field" by both informal and formal communication systems. Both the NASA and the DOD maintain formal scientific and technical information (STI) systems for acquiring, processing,

announcing, publishing, and transferring aeronautical research required for and resulting from their R&D activities. A variety of information products and services are utilized by these STI systems. According to Stohrer, within both the NASA and the DOD STI systems, the U.S. government technical report is used as a primary means of transferring the results of U.S. government -performed and -sponsored R&D to the aeronautical community.[15]

The Problem

The technical report is considered to be a primary information product for the transfer of knowledge within the aeronautical community. Auger states that "the history of technical report literature in the U.S. coincides almost entirely with the development of aeronautics, the aviation industry, and the creation of the NACA, which issued its first technical report in 1915."[16,17] In her study, Information Transfer in Engineering, Shuchman reported that 75 percent of the engineers surveyed used technical reports, that technical reports were important to engineers doing applied work, and that aerospace engineers referred to "key" persons and technical reports more than any other group of engineers.[18]

What role does the U.S. government technical report play in the transfer of knowledge in aeronautics? According to McClure, the technical report has been variously studied over the last thirty years. In many of these studies, however, it is often unclear, as is the case in Shuchman's study, whether

U.S. government technical reports, non-U.S. government technical reports, or both were included.[19] There is some historical evidence to support the claim that the U.S. government technical reports produced by the NACA played a crucial role in transferring the results of research to the aeronautical community. Roland states that "NACA technical reports were sought after and exploited by aeronautical engineers (and scientists) throughout the U.S. and abroad."[20] However, the research infrastructure of the American aviation industry has changed dramatically since the NACA was created in 1915 by the Congress "to supervise and direct the scientific study of the problems of flight with a view to their practical solutions"[21] and since the NASA was established "to plan, direct, and conduct aeronautical and space activities."[22]

What, then, is the role of the U.S. government technical report in an industry that has matured, is becoming more interdisciplinary in nature, and is becoming more global and international in scope? Is the U.S. government technical report a primary information product for transferring knowledge within an STI system for aeronautics? What role does the U.S. government technical report play in the use and production of STI by aeronautical engineers and scientists? What role does the U.S. government technical report play in knowledge production, knowledge transfer, and knowledge utilization within aeronautics?

Purpose of the Study

The study will explore the production, transfer, and use of STI by aeronautical engineers and scientists for the purpose of determining the role of the U.S. government technical report in aeronautics. A secondary purpose will be to create a knowledge base regarding the production, transfer, and use of STI by aeronautical engineers and scientists. The purposes of the study will be accomplished through the completion of the following objectives.

1. To determine the extent to which the purpose (task) for which information is used and information source selection are affected or influenced by such structural and institutional factors (variables) as education, academic preparation, type of organization, professional duties, and technical discipline.

2. To determine the extent to which the selection of an information source is affected or influenced by such factors as accessibility, expense, familiarity, relevance, ease of use, timeliness, technical quality, and comprehensiveness.

3. To identify the attitudes of aeronautical engineers and scientists toward and use of information technology in an effort to predict its potential value for STI production, transfer, and use in aeronautics.

4. To identify the attitudes toward and use of sci-tech libraries and technical information centers in an effort to determine their role in a formal STI system for aeronautics.

5. To determine the extent to which there may be discontinuity between the Federal systems that acquire, process, announce, and distribute STI to the aeronautical community and the aeronautical engineers and scientists to whom the STI is directed.

Significance of the Study

This study is significant for three reasons. First, it will help fill a knowledge void by providing a basic understanding of the production, transfer, and use of STI by aeronautical engineers and scientists. Previous studies have either examined or focused on the information needs and use of engineers and scientists in a particular facility, installation, or organization. Furthermore, there are numerous gaps, ambiguities, and unanswered questions regarding the production, transfer, and use of STI by engineers and scientists in general and aeronautical engineers and scientists in particular.

In many of these studies, engineers and scientists have been lumped together, favoring "scientists" as a more generic term. Allen notes that this practice "is especially self-defeating in information [production, transfer, and] use studies because confusion over the characteristics of the sample has led to what appears to be conflicting results and to a great difficulty in developing normative measures for improvement of the information systems in either science or technology."[23] Joenk supports Allen's statement, stating that "the primary difference between engineers and scientists leads to different philosophies and habits not only about contributing to the technical literature but also to using the technical literature and other sources of information."[24]

Second, it will help fill a knowledge void by providing a basic understanding of the role of the U.S. government technical report in the production, transfer, and use of STI in aeronautics. Of the information product studies previously conducted, few have focused on the U.S. government technical report. On the subject of these studies, McClure states that "it is often unclear whether U.S. government technical reports, non-government technical reports, or both were included."[25] Furthermore, McClure states that previous information product studies have focused on the "use" or selection of technical reports as sources of information, not on their production or role in the transfer of STI. Such studies have been cast in the larger context of scientific communication and the information seeking behavior of engineers and scientists. Because of competing or unclear definitions, the results of many of these studies are non-comparable.[26] Consequently, there are insufficient empirically derived data from which accurate conclusions can be drawn regarding the role of the U.S. government technical report in aeronautics.

Third and final, the knowledge gained on the production, transfer, and use of STI in aeronautics and the role that the U.S. government technical report plays in this process should be useful in two ways. It is likely that increased knowledge and understanding of the problem could be helpful to Federal agencies in developing policies relating to the production,

transfer, and use of government funded R&D and industrial innovation and productivity in aeronautics. It is also likely that increased knowledge and understanding of the problem could be useful to Federal agencies in developing and implementing STI systems, for evaluating existing STI systems, and for developing/evaluating Federal STI policy as it applies to aeronautics.

Limitations of the Study

1. The study will be limited to a particular situation and will describe the production, transfer, and use of STI by aeronautical engineers and scientists at only one point in time in the U.S.

2. The list of individuals in the sample population is dependent upon the completeness, accuracy, and up-to-dateness of the AIAA membership list.

3. The study will be limited by the selection of the time period of five months from October 15, 1988, to February 15, 1989.

4. The accuracy and validity of the data are limited by the exactness and thoroughness with which the respondents supply the needed information.

5. All of the limitations placed on information gathered through the use of survey research will be applicable to this study.

6. The study is concerned with the production, transfer, and use of STI by aeronautical engineers and scientists and does not address other aspects of information. Therefore, the study will not be concerned with the communication of other types of information such as budgets, schedules, or personnel, although they may be of general interest to aeronautical engineers and scientists.

7. The results of the study will be generalizable to the production, transfer, and use of STI in aeronautics. The results will not, however, be generalizable to the production, transfer, and use of STI in other disciplines.

8. The results of the study will be generalizable to the role of the U.S. government technical report in aeronautics. The results will not, however, be generalizable to U.S. government technical reports in other disciplines, to all U.S. government technical reports, or to all U.S. government documents.

9. The study is concerned with the U.S. government technical report as an information product, not as a rhetorical device. Therefore, the organization, language, and graphic presentation of the content, as well as adherence to production or editorial guidelines, fall outside the scope of this study.

10. The results of the study will not be generalizable to all sci-tech libraries and technical information centers. The results also may not be generalizable to all aeronautical sci-tech libraries and technical information centers.

11. The study is concerned with innovation and the diffusion of knowledge only to the extent to which these areas contribute to an understanding of the production, transfer, and use of STI in aeronautics. Therefore, while the results of the study might contribute to a general understanding of these two areas, the results will not determine either the diffusion of innovation or knowledge in aeronautics.

12. The study is concerned with Federal STI policy only to the extent to which it may contribute to any discontinuity between the Federal systems that acquire, process, announce, and distribute STI to the aeronautics community and the aeronautical engineers and scientists to whom the STI is directed.

Definitions of Terms

The terms employed most frequently in the study are defined below. Definitions are given to help clarify the various interpretations that could be made of the several terms used throughout the study.

1. Aeronautical Engineers and Scientists -- for purposes of this study, this is a "generic" term that includes those engineers and scientists who, regardless of their training, are involved in the design, development, testing, manufacture, and operation of aircraft, space vehicles, and related components and systems.

2. Aeronautics -- the basic scientific knowledge and principles underlying the design, manufacture, and operation of aircraft, space vehicles, and related components and systems.

3. AIAA Special Interest Groups -- includes aerospace science; aircraft systems; structures, design, and test; propulsion and energy; aerospace and information systems; and administration/management.

4. Applied Research -- research directed toward gaining knowledge or understanding necessary for determining the means by which a recognized and specific need may be met.

5. Basic Research -- research primarily concerned with gaining a fuller understanding or knowledge of the subject under study rather than a practical application thereof.

6. Descriptive Research -- a type of research or research strategy that seeks to explore or describe what is happening or has happened; it involves the collection of data to answer questions concerning the current status of a subject or study. Descriptive data are usually collected through survey questionnaires, interviews, observations, or document analysis.

7. Education -- for purposes of this study education is defined as no degree, a bachelors degree, a masters degree, or doctorate in some area or discipline of science or technology.

8. Endogenous Variables -- as used in path analysis, variables that have at least one hypothesized cause in the path analysis model.

9. Exogenous Variables -- as used in path analysis, variables that lack hypothesized causes in the path analysis model.

10. <u>Formal Sources</u> -- sources of information best characterized as involving the use of materials such as books, journals, technical reports, data bases, and interaction with information professionals such as librarians and information specialists.

11. <u>Gatekeeper</u> -- a person who, because of certain personal characteristics such as leadership, intelligence, and experience in the field, acts as a filter of information to and from the other members of a group or organization and may link them to other sources of information both inside and outside of the group or organization.

12. <u>Informal Sources</u> -- sources of information best characterized as involving personal contact with a variety of individuals such as colleagues, supervisors, consultants, and vendors.

13. <u>Information Source Selection Criteria</u> -- for purposes of this study information source selection criteria include accessibility, cost, comprehensiveness, ease of use, familiarity or experience, relevance, and technical quality or reliability.

14. <u>Obtrusive Research</u> -- methods of research whereby the researcher intrudes to some degree into whatever is being studied or investigated; examples include experimental and survey research.

15. <u>Professional Duties</u> -- for purposes of this study professional duties include research, administration/management, design/development, manufacturing/production, marketing/sales, private consultant, service/maintenance, and teaching/academic.

16. <u>Research</u> -- the systematic, intensive study directed toward fuller knowledge or understanding of a particular subject.

17. <u>Research and Development</u> -- the systematic use of knowledge and understanding gained from research and directed toward the production of useful materials, devices, systems, or methods, including design and development of prototypes and processes.

18. <u>Research and Technology</u> -- the initial phase of research and development, which consists of activities primarily aimed at producing physical understanding; new concepts; design data; and

validated design procedures for aircraft systems, subsystems, and components; it consists of activities ranging from theoretical analysis to laboratory investigations to flight-testing experiment aircraft.

19. <u>Sci-Tech Library</u> -- a library with a special collection of materials which is usually limited by subject (for example, aeronautics) or form (for example, technical reports) in accordance with the interests of its users. In a functional sense, these libraries operate in support of a special purpose or activity determined by the mission of the sponsoring organizations. Organizationally, these libraries may be found in academic settings, in large public libraries, in business and industry, in government, and in not-for-profit organizations.

20. <u>STI</u> -- for purposes of this study STI is defined as information used for or resulting from R&D activities and includes such types and kinds of information as basic scientific data, experimental techniques, codes of standards and practices, design procedures and methods, computer programs, government rules and regulations, in-house technical data, product and performance characteristics, economic and business data, and patent specifications.

21. <u>STI Products and Services</u> -- that phase of scientific communication that deals with secondary sources of scientific and technical information and the surrogation of the primary literature by creating various information products and services. These products and services include current awareness services, bibliographies, indexes, abstracts, and databases designed to facilitate the identification and selection of pertinent information appropriate for a given purpose.

22. <u>Survey Research</u> -- a type of research or research strategy that attempts to collect data from members of a population by taking a sample from the population in order to determine the current status of that population with respect to one or more variables. The instrument most frequently associated with survey research is the survey questionnaire.

23. Technical Discipline -- for purposes of this study technical disciplines include aeronautics, astronautics, chemistry and materials, communications, computational fluid dynamics, engineering, fluid mechanics, geosciences, life sciences, math and computer science, physics, psychology, and space sciences.

24. Technical Information Center -- an organizational unit created for the purpose of acquiring, processing, and disseminating scientific and technical information. These centers are usually limited by subject, are frequently found in business and industry, and usually have a library and staff of information professionals who extract, evaluate, and index scientific and technical information.

25. Technical Report -- a subset of government documents; an information product that documents the results of U.S. government -performed and -sponsored research and development. These reports are published by an agency of the U.S. government; have a unique, issuer-supplied report number; may have a contract or grant number and an accession number; and, after initial distribution, may be obtained from a clearinghouse such as the National Technical Information Service, the Defense Technical Information Center, or the NASA Scientific and Technical Information Facility.

26. Technologists -- for purposes of this study the terms technologists and engineers are used interchangeably. According to the 1987 edition of the Occupational Outlook Handbook, engineers [and technologists] apply the theories and principles of science and mathematics to the economical solution of practical technical problems.

27. Type of Organization -- for purposes of this study type of organization includes academic, government, industry, and not-for-profit.

Glossary

ADD	Automatic Document Distribution
AEC	Atomic Energy Commission
AGARD	Advisory Group for Aerospace Research and Development, North Atlantic Treaty Organization

AIAA	American Institute for Aeronautics and Astronautics
APA	American Psychological Association
ARIST	Annual Review of Information Science and Technology
ASTIA	Armed Services Technical Information Agency
CAB	Current Awareness Bibliography
CFSTI	Clearinghouse for Federal Scientific and Technical Information
COSATI	Committee on Scientific and Technical Information, U.S. Federal Council on Science and Technology
CUFT	Center for the Utilization of Federal Technology, National Technical Information Service
DDC	Defense Documentation Center, Department of Defense
DLA	Defense Logistics Agency
DOD	Department of Defense
DOE	Department of Energy
DROLS	Defense RDT&E On-Line System
DTIC	Defense Technical Information Center Department of Defense
EDB	Energy Database
ERA	Energy Research Abstracts
ERDA	Energy Research and Development Administration
ERIC	Educational Resources Information Center Department of Education
FEDRIP	Federal Research in Progress
GRA&I	Government Reports Announcements and Index
GPO	Government Printing Office

IAA	International Aerospace Abstracts
IEEE	Institute of Electrical and Electronics Engineers
IR&D	Independent Research and Development
ITIS	Integrated Technical Information System
LC	Library of Congress
LISA	Library and Information Science Abstracts
NACA	National Advisory Committee for Aeronautics
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NIH	National Institutes of Health
NSA	Nuclear Science Abstracts
NTIS	National Technical Information Service
OARS	OSTI Automated Retrieval System
ONR	Office of Naval Research
OSRD	Office of Scientific Research and Development
OSTI	Office of Scientific and Technical Information, Department of Energy
OTA	Office of Technology Assessment, U.S. Congress
OTS	Office of Technical Services
PB	Publications Board
PEDS	Program Element Descriptive Summaries
Ph.D.	Doctor of Philosophy
R&D	Research and Development
R&M	Reports and Memoranda
R&T	Research and Technology
RECON	Remote Console

RIP	Research in Progress
S&T	Scientific and Technical
SATCOM	Scientific and Technical Communication (Committee on), National Academy of Science -- National Academy of Engineering
SCAN	Selected Current Aerospace Notices
Sci-Tech	Science and Technology
SLA	Special Libraries Association
SPSS-X	Statistical Package for the Social Sciences X
SRIM	Selected Research in Microfiche
STAR	Scientific and Technical Aerospace Reports
STI	Scientific and Technical Information
STIF	Scientific and Technical Information Facility, National Aeronautics and Space Administration
STP	Science and Technology Project
TAB	Technical Abstract Bulletin
TDM	Total Design Method
TIC	Technical Information Center, Department of Energy
TR	Technical Report
TRAC	Technical Report Awareness Circular
UMI	University Microfilms International
U.S.	United States
WUIS	Work Unit Information System

REVIEW OF RELATED RESEARCH AND LITERATURE

Related research and literature will be identified, reviewed, and analyzed as part of understanding, defining, and establishing a theoretical and conceptual framework for the problem and its context. The following topics will be used as part of the review of related research and literature:

- The history and development of technical reports
- Users and uses of technical reports
- Users and uses of STI
- Engineers and information use
- Engineers and communication
- Engineers and information transfer
- Diffusion of knowledge
- Diffusion of innovation
- Federal STI policy

The search for sources of related research and literature will include (1) searches of print and computerized databases including Dissertation Abstracts, Engineering Index, Compendex, ERIC, Information Science Abstracts, LISA, NTIS, and SCISEARCH; and (2) the Annual Review of Information Science and Technology (ARIST), books, periodicals, reports, conference proceedings, encyclopedias, and bibliographies using the aforementioned topics.

PART I - THE U.S. GOVERNMENT TECHNICAL REPORT

The U.S. government technical report is a primary means by which the results of federally funded R&D are reported. Since World War II, the number of U.S. government technical reports has increased as the Federal government has assumed a greater role in the funding of R&D in the U.S. Approximately 70,000 technical report titles are added annually to the National Technical Information Service (NTIS)[27]. According to McClure, U.S. government technical reports "may constitute the single most important storehouse of R&D results in the world."[28] These reports are a primary means by which the results of federally funded R&D are made available to the scientific and technical (S&T) community and are added to the literature of science and technology.

Characteristics of Technical Reports

The definition of the technical report varies because it serves different roles in communicating within and between organizations. The technical report has been defined etymologically according to report content and method,[29] behaviorally according to the influence on the reader,[30] and rhetorically according to the function of the report within a system for communicating STI.[31] The boundaries of technical report literature are difficult to establish because of wide variations in the content, purpose, and audience being

addressed. The nature of the report -- whether it is informative, analytical, or assertive -- contributes to the difficulty.

Fry points out that technical reports are heterogenous, appearing in many shapes, sizes, layouts, and bindings.[32] According to Smith, "their formats vary; they might be brief (two pages) or lengthy (500 pages). They appear as microfiche, computer printouts or vugraphs, and often they are looseleaf (with periodic changes that need to be inserted) or have a paper cover, and often contain foldouts. They slump on the shelf, their staples or prong fasteners snag other documents on the shelf, and they are not neat."[33]

Technical reports may exhibit some or all of the following characteristics:[34,35]

- o publication is not through the publishing trade;
- o readership/audience is usually limited;
- o distribution may be limited or restricted;
- o content may include statistical data, catalogs, directions, design criteria, conference papers and proceedings, literature reviews, or bibliographies; and
- o publication may involve a variety of printing and binding methods.

The National Academy of Sciences -- National Academy of Engineering Committee on Scientific and Technical

Communication[36] lists the following characteristics of the technical report:

- it is written for an individual or organization that has the right to require such reports;
- it is basically a stewardship report to some agency that has funded the research being reported;
- it permits prompt dissemination of data results on a typically flexible distribution basis; and
- it can account the total research story, including exhaustive exposition, detailed tables, ample illustrations, and full discussion of unsuccessful approaches.

The Role of the Technical Report in S&T Communication

Technical reports and S&T journals are two of the primary information products used by engineers and scientists to communicate the results of their research. The choice of whether to publish the results of federally funded R&D in a technical report or an S&T journal depends on such factors as the nature of communication within the discipline, the type of information being reported, the reporting requirements of the sponsoring Federal agency, the timing of dissemination, and the need for selective or controlled dissemination. In practice, however, the technical report is favored as a recording medium of R&D and is, therefore, used by engineers and technologists, while the S&T journal appears to be favored as the recording medium of basic research and is, therefore, used by scientists.[37]

During the past forty years, the technical report has developed into an important medium of communication in science

and technology to the extent that it has sometimes been viewed as a threat to the S&T journal.[38] However, the technical report has been accused of not meeting the same criteria or standards of authority, scientific rigor, and retrievability as S&T journal articles.[39] Much of the debate concerning technical reports centers around the following four themes: (1) availability,(2) quality,(3) diversity of content, and (4) status as primary information products, especially in relationship to S&T journals.[40]

History and Growth of Technical Report Literature

In describing the development of S&T communication, Grogan states that dissemination of research results was made first through personal correspondence and then through papers given at society meetings.[41] As science became more specialized and institutionalized, the S&T journal became the accepted method of reporting research results. However, as the growth of science and technology began to escalate rapidly, the S&T journal was no longer capable of meeting the total information needs of engineers and scientists. According to Grogan, the technical report emerged as an alternative method of disseminating the results of research.[42]

The development of the [U.S. government] technical report as a major means of communicating the results of R&D, according to several authorities such as Godfrey and Redman,[43] dates back to 1941 and the establishment of the U.S. Office of Scientific Research and Development (OSRD). Further, the

The justification for federally funded science and technology follows the argument, advanced in Science: The Endless Frontier,[50] that government funded research in science and technology serves as a means to improve health, defend the nation, fuel economic growth, and provide jobs in new industries. Events such as the Korean War, Sputnik, the increased use by government of science and technology to solve social problems in the late 1960s and 1970s, the energy crisis, and the growing sophistication of the USSR account for the growth of federally funded research in science and technology.[51,52]

The expanding role of the Federal government in science and technology, which increased dramatically after World War II, resulted in significant changes in STI activities in the U.S. These changes, which were necessary to handle the increased production of federally funded R&D, included new methods of publishing, disseminating, and retrieving STI. According to Adkinson, a significant change occurred during this period in the way the results of research were disseminated. In the past, there had been almost complete reliance on dissemination through traditional journals and monographs; now the use of the [U.S. government] technical report became widespread.[53]

As the number of U.S. government technical reports increased, so too did the need to make these reports available. In response, the largest producers of U.S.

government technical reports -- namely the Department of Defense, Department of Energy, and the National Aeronautics and Space Administration -- created information "facilities" and specialized information services to acquire, announce, reproduce, and distribute technical reports. At the same time, the rapid advances in computer technology were applied to indexing and abstracting and the creation of a variety of Federal online databases for government technical reports. Also, the NTIS was established as the central source for the public sale of technical reports containing the results of research performed or sponsored by the U.S. government.

The principle Federal agencies responsible for R&D are listed below with their corresponding information activity. Each agency's information activity and the NTIS are briefly discussed.

- Department of Defense (DOD)
  Defense Technical Information Center (DTIC)
- Department of Energy (DOE)
  Office of Scientific and Technical Information (OSTI)
- National Aeronautics and Space Administration (NASA)
  Scientific and Technical Information Facility (STIF)
- U.S. Department of Commerce
  National Technical Information Services (NTIS)

Defense Technical Information Center

The Defense Technical Information Center (DTIC), located in Cameron Station, Alexandria, Virginia, is the central point within DOD for acquiring, storing, retrieving, and

disseminating STI to support the management and conduct of DOD research, development, engineering, and studies programs.[54] Access to defense-related research began in 1947, when the Office of Naval Research (ONR) contracted with the Library of Congress (LC) to establish the Science and Technology Project (STP) to catalog and abstract Navy technical reports and provide bibliographic services for them.[55]

In 1951, the Armed Services Technical Information Agency (ASTIA) was established by the Secretary of Defense to coordinate and consolidate all DOD STI activities. In 1963, ASTIA was renamed the Defense Documentation Center (DDC) and its operational control was transferred to the Defense Logistics Agency (DLA). In 1979, the DDC became known as the DTIC to better reflect the scope of its mission and functions. While still under the operational control of DLA, DTIC receives policy guidance from the Deputy Under Secretary of Defense for Research and Advanced Technology.[56]

The DTIC technical reports database of approximately two million records grows by approximately 30,000 technical reports a year. DTIC products and services are based on and derived from the technical reports database and the Defense R&D Management Information database, including the Work Unit Information System (WUIS), the Independent Research and Development (IR&D), and the Program Element Descriptive Summaries (PEDS) databases.

Approximately 50 percent of the technical reports accessioned each year into the DTIC technical reports database are unclassified and unlimited in distribution. These reports are made available, along with technical reports that are classified and limited in distribution, to DTIC registered users. Technical reports that are unclassified and unlimited in distribution are also sent to the NTIS.

DTIC has created a variety of STI products and services to provide access for registered users to its technical report collection and database. The Defense RDT&E Online System (DROLS) is an interactive system linking remote terminals, both classified and unclassified, to the DTIC databases and is used for both input and retrieval. Users can order bibliographies, management data reports, and technical reports directly from their terminals. The Technical Report Awareness Circular (TRAC), which replaced TAB (Technical Abstracts Bulletin), is the unclassified/unlimited announcement journal for unclassified/unlimited, unclassified/limited, and classified DOD technical reports. TRAC, which is published monthly, includes citations but no abstracts or subject index, contains five indexes, and has a semiannual/annual index that is published on microfiche.

The Current Awareness Bibliography (CAB) is a customized, user specific, automated bibliography that is most often based on subject terms. Contract numbers, technical report numbers, corporate authors, sponsoring organizations,

or any combinations of the above can be used to created CAB bibliographies. Every two weeks the user's interest profile is matched against newly accessioned technical reports, and the selected citations are sent to the subscriber. Under the Automatic Document Distribution (ADD) program, DTIC users establish profiles of their interests; every two weeks they receive microfiche copies of newly acquired technical reports that match those interests.[57]

<u>Department of Energy - Office of Scientific and Technical Information</u>

The Department of Energy (DOE) STI system is administered by the Office of Scientific and Technical Information (OSTI), which is located at the Technical Information Center (TIC) facility in Oak Ridge, Tennessee. The DOE STI system originated in 1942 with the Technical Information Service (TIS) of the Atomic Energy Commission (AEC). TIS became the Technical Information Center of the Energy Research and Development Administration (ERDA) and then the Technical Information Center of DOE.

The DOE technical report collection, currently 775,000 reports, grows by about 20,000 reports annually. DOE technical reports are distributed through a selective automatic distribution system. Unclassified/unlimited reports are supplied to NTIS and the Government Printing Office (GPO) for further distribution to academic institutions, industry, and the public.[58]

OSTI has created a variety of STI products and services, including three databases: The Energy Database (EDB), which covers all aspects of energy and energy sources; Nuclear Science Abstracts (NSA), which cover international nuclear science and technology research; and Research in Progress (RIP), which covers recently completed and on-going projects funded by DOE. The EDB and NSA are available to the U.S. S&T community through DIALOG Information Services. The RIP database and a one-year window of EDB are available to the DOE and its contractor community through the Integrated Technical Information System (ITIS) which is available through the DOE national online information retrieval network, OSTI Automated Retrieval System (OARS). OSTI also publishes a variety of current awareness documents, including Energy Research Abstracts, a biweekly announcement journal for technical reports; Energy Abstracts for Policy Analysis, a monthly announcement journal covering policy-related energy literature; and a variety of specialized bulletins covering such topics as acid precipitation and laser research.[59]

NASA Scientific and Technical Information System

The NASA Scientific and Technical Information (STI) System is administered by the Scientific and Technical Information Division. The mission of the NASA STI system is twofold: to acquire worldwide research information in aeronautics, space, and related disciplines and to contribute to the expansion of knowledge through the timely dissemination

to the aerospace community of the results of NASA -performed and -sponsored research.[60] NASA was created in 1958 by the National Aeronautics and Space Act (P.L. 85-568) to supersede the NACA, an agency which published its first technical report in 1915.

The NASA STI collection of 1.2 million documents grows by approximately 20,000 technical reports each year. Like those of DOE, NASA technical reports are distributed through an automatic distribution system. Unclassified/unlimited reports are supplied to NTIS and GPO for further distribution to academic institutions, industry, and the public. NASA technical reports that are classified for reasons of national security, restricted or limited in distribution, or otherwise not publicly available are obtained from the NASA STIF, located at the Baltimore/Washington International Airport.

The NASA STI system utilizes a variety of information products and services to provide access to the NASA technical report collection and database. Scientific and Technical Aerospace Reports (STAR) is an announcement journal that covers worldwide aerospace technical report literature. Selected Current Aerospace Notices (SCAN) is a current awareness publication that supplements STAR by providing users with computer-generated citations to new reports announced in STAR. The NASA database is accessible to authorized users

through RECON, the NASA computerized online interactive retrieval system. The NASA STI database is commercially available through the NASA/AIAA Aerospace Database.

National Technical Information Service

National Technical Information Service (NTIS) has its origin in the Publications Board (PB), which was established in 1945. Its purpose was to collect and distribute unclassified and declassified technical reports produced by the U.S. government agencies and foreign government research agencies, as well as reports captured in World War II. In 1946, the name of the Board was changed to the Office of Technical Services (OTS). In 1964, OTS was renamed the Clearinghouse for Federal Scientific and Technical Information (CFSTI). In 1970, CFSTI was abolished and its function was transferred to the newly created NTIS.[61]

The NTIS bibliographic database is composed of unclassified/unlimited and declassified U.S. government technical reports which are accessioned by DOD, DOE, and NASA and sent to NTIS on magnetic tape. These tapes are merged with entries from other Federal, non-Federal, and foreign sources every two weeks to produce the NTIS Bibliographic Database Update File, which is distributed to a number of commercial vendors for online access.[62]

Technical reports acquired by NTIS are announced in Government Reports Announcements and Index (GRA&I), which is published biweekly and may be purchased directly from NTIS in

paper copy or microfiche. The reports may be received automatically through a biweekly current awareness service, Selected Research in Microfiche (SRIM), which provides full-text microfiche copies of reports selected by means of a pre-established interest profile. Other NTIS products and services include the NTIS Abstract Newsletter, a current awareness service; access to bibliographic databases from other U.S. government agencies; and access to Federal Research in Progress (FEDRIP), computer software, translations, government patent information, and various fact sheets.[63]

Selected Research Findings

The technical report has been variously studied over the last thirty years. As previously mentioned, however, it is often unclear whether U.S. government technical reports, non-government technical reports, or both were included. As with the technical report studies, there are many contradictions, gaps, ambiguities, and unknown answers regarding the use, production, impact, and value of U.S. government technical reports.[64]

To help develop the conceptual framework for the study, studies concerned with U.S. government technical reports are grouped into the following four topics or themes:

- role in the Federal STI system
- role in Federal mission-oriented STI programs

- role in S&T communication
- historical development, use in specific disciplines, obsolescence, problems, coverage, and research needs

Selected findings, recommendations, and contributions addressing these topics have been summarized. Although not intended to be comprehensive, this material is presented to set the general tone of the research and literature related to technical reports and U.S. government technical reports.

Role in the Federal STI System

Year	Author	Findings and Recommendations
1962	Crawford	Recognized that government technical reports constitute an important element in STI system; their principle value (use) is in the documentation of federally funded research. Government technical reports should be stored in an organized collection and placed under bibliographic control to facilitate their announcement, accessibility, and availability to the S&T community.
1963	Weinberg	Recognized the problems that the proliferation of government technical reports caused the library and information community. Government has the obligation to publish all significant R&D findings; critical reviews, similar to those given S&T journal literature should be applied to government technical reports; government-wide clearinghouses should established to help integrate the results of government funded R&D in the literature of science and technology;and the OTS should become a complete sales agency for government technical reports.
1964	Elliott	Recognized the importance of technical reviews; concern as to the type(s) of controls placed on dissemination; and the need to properly index, abstract, and make government technical reports accessible to the S&T community. A single clearinghouse to coordinate Federal STI documentation and dissemination activities is needed; furthermore, the need exists to

		ensure that classified or otherwise restricted government technical reports do not remain unavailable to the S&T community any longer than is essential to the national interest.
1968	COSATI	Recognized that the government technical report and the S&T journal are both essential in disseminating the results of federally funded R&D; both play important and different roles in S&T communication. Federal report-producing agencies must insist on full and high-quality reporting of all government funded research.
1969	SATCOM	Recognized the need to communicate more effectively the results of federally funded R&D; recognized the role of the government technical report in documenting and disseminating these results. Government technical reports must be given uniform and adequate bibliographic control; the writing and presentation of data must be improved; accessibility, through better and more fully coordinated announcement, must be increased; and maximum coordination between government technical reports and S&T journals must occur to minimize confusion and undesirable duplication.

Role in Federal Mission-Oriented STI Programs

Year	Agency	Author	Contributions
1965 1966	DOD DOD	Berul Goodman	DOD User-Needs Studies -- first large scale attempts by a major component of the Federal R&D community to determine the "broad picture" and understanding of information acquisition, flow, and use of STI (including DOD technical reports) within a large segment of the R&D community.
1983	DOD/ DTIC	Roderer	Use and Value of DTIC Products and DTIC Services -- attempted to determine the economic value associated with DTIC products, including DOD technical reports; determined use, purpose of use, and readership of DOD technical reports.
1982	DOE/ TIC	King	Value of Energy Database -- TIC attempted to determine the economic value of the DOE energy database; determined time spent reading DOE technical reports and the use and purpose for using DOE technical reports.
1979 1980 1981	NASA NASA NASA	Monge Pinelli Pinelli	Assessment of NASA Technical Information -- concerned with the dissemination and utilization of NASA STI within the aeronautics industry; determined the knowledge and use of NASA STI products and services, and the perceived quality and usefulness of NASA technical reports.

1982	NASA	McCullough	NASA Technical Report Format -- concerned with the NASA technical report as a rhetorical device; analyzed and compared the NASA technical report format with current practice and usage.
1982	NASA	Pinelli	

Role in S&T Communication

Year	Author	Findings and Recommendations
1956/1957	Gray & Rosenborg	Most "publishable" STI contained in unclassified defense-related government technical reports did find its way into the S&T literature but the process was slow. Authors should be encouraged to publish "publishable" findings promptly; government technical reports should be accessible to the S&T community several years after publication.
1961/1962	Herner & Herner Herner & Kolber	Probability of a government technical report appearing in a non-government abstracting and indexing service was low; average time from issuance to announcement of DOD technical reports in U.S. government announcement literature was slow. Federal government should take the necessary steps to encourage non-government abstracting and indexing services to include government technical reports and the process of announcing DOD technical reports should be expedited.

1962	O'Donnell	The Federal systems used to disseminate government technical reports were ineffective and in some cases wasteful. A coordinated government-wide policy for technical report documentation and dissemination is necessary.
1964	Ronco	Virtually no empirical work had been conducted to determine the effectiveness of government technical reports as communication devices. Federal technical report-producing agencies should develop methods to test the effectiveness of technical reports as dissemination devices. Experimental formats for technical reports should be developed and tested to determine their effectiveness.

Historical Development, Use in Specific Disciplines, Obsolescence, Problems, Coverage, and Research Needs

Year	Author	Contributions
1952, 1962 1962, 1970	Miller, Tallman Kee, Boylan	Traced the historical development of government technical reports.
1953, 1961 1965, 1967,1969 1973	Cobb, Burton & Green, Garvey & Griffith, Fuccillo Coile	Discussed the use of government technical reports in electrical and electronic engineering, in psychology, physics, and in biomedicine.
1967, 1969 1973, 1975 1976, 1981	Houghton, Passman Brearley, Auger Grogan, Subramanyam	Discussed the role of the government technical report in S&T communication.
1958, 1959 1960, 1974	Wilson, Randall Kebler, Anderson	Discussed obsolescence and "half-life" of government technical reports.
1952, 1953 1970, 1975	Bennington, Fry Boylan, English	Discussed the organization and management of government technical reports.
1953, 1965/ 1966, 1978	Woolston, Redman Hartas	Discussed problems with obtaining, handling, processing, and controlling technical reports.
1959, 1986 1988	Herner & Herner McClure	Discussed government technical report coverage and research needs.

Discussion

The U.S. government technical report is a primary means by which the results of federally funded R&D are made available to the S&T community and are added to the literature of science and technology. Although the government technical report has been variously reviewed, compared, and contrasted, there is no real knowledge base regarding the role, production, use, and importance of the U.S. government technical report.

The body of available knowledge is simply inadequate and incomparable to make such determinations. Most of the available knowledge is largely anecdotal, is limited in scope and dated, and is unfocused in the sense that it lacks a conceptual framework. The available knowledge does not lend itself to developing "normalized" answers to questions regarding the U.S. government technical report.

The following narrative is offered to illustrate this position. Regarding the question of the "active life" or half life or obsolescence of government technical reports, McClure et al.,[65] who quote Newman and Amir,[66] state that the active life of U.S. government technical reports seldom exceeds seven years. Anderson, on the other hand, states that the NACA reports "do not have a half life."[67] Both studies are based on single case library use. The Newman and Admir study took place at Johns Hopkins, was concerned with technical reports covering primarily physics and electronics, and was

based on circulation statistics. Anderson's study took place at Cal-Tech, was concerned with technical reports covering aeronautics, and was based on actual library use. The results of both studies are limited in terms of their comparability and generalizability.

The studies performed by King Research[68,69] regarding the value of the DOE energy database and DOD STI products and services, involved participants who were "subscribers" or known users of the DOE and DOD systems. Because of this methodological approach, the results of the studies are limited in terms of their generalizability. The results tell little or nothing about non-users of the systems and are not generalizable to the larger issues concerning U.S. government technical reports.

There is also a noticeable absence of program or evaluative research and U.S. government technical reports. Several Congressional and task force studies recommended that mechanisms [systems] should be established to ensure prompt and proper availability [distribution] of government technical reports to the S&T community. In the course of the approximately twenty five years since the recommendations were made, only two such studies have been undertaken. Each of these studies was conducted more than twenty years ago.[70,71] There is also a noticeable absence of empirically based research in the field of library and information science devoted to or concerned with U.S. government technical

reports. A review of the research and literature revealed no library science dissertations specifically concerned with U.S. government technical reports and only one dissertation tangent to U.S. government technical reports.[72]

Much more knowledge and understanding of the U.S. government technical report is needed if its role in the broader process of S&T communication is to be understood. Research related to the U.S. government technical report might include the following questions.

- To what extent is the government technical report an effective means for transferring the results of government funded research to the S&T community?
- To what extent is the government technical report capable of increasing U.S. industrial innovation, productivity, and competitiveness?
- To what extent may barriers to the transfer process exist that may decrease the utilization of government technical reports?
- Does Federal STI policy concerning government technical reports inhibit or restrict the transfer of federally funded research results to American industry?
- Can experimental methodologies be developed that can measure the effectiveness of government technical reports as dissemination devices?

Much more knowledge and understanding is needed about technical reports, their role, importance, production, use, value, and impact on industrial productivity and innovation. This knowledge and understanding is needed to develop STI policy and to design and implement information systems that

will permit maximum access to U.S. government technical reports and foster the maximum exploitation of their material content.

PART 2 - INFORMATION PRODUCTION, TRANSFER, AND USE IN ENGINEERING

Science, Government, and Information (the Weinberg Report), which was concerned with determining the responsibilities of the technical community and the government in the transfer of S&T information, reached the following conclusions:[73]

- the transfer of information is inseparable from R&D,
- the transfer of information is strongly affected by the attitudes and practices of the originators of scientific information, and
- adequate [science] communication is a prerequisite for strong science and technology.

Consequently, understanding the ways in which engineers and scientists produce, transfer, and use STI may be critical to understanding and maximizing the effectiveness of the R&D process, to lessening the possible fragmentation and ineffectiveness of S&T, to increasing U.S. industrial productivity and innovation, and to maximizing the economic competitiveness and vitality of the country.

User Studies

According to Menzel, "user studies" represent a take-off point for empirical research on the information needs and uses of engineers and scientists.[74] In 1978, Crawford estimated

that "over the past 30 years, some 1,000 papers on information needs and use have been published."[75] Menzel provides the following rationale for undertaking user studies in science and technology.

> The way in which engineers and scientists make use of information at their disposal, the demands that they put on them, the satisfaction achieved by their efforts, and the resultant impact on their future work are among the items of knowledge which are necessary for the wise planning of science information systems and policy.[76]

Paisley offers three reasons why so many user studies have been conducted: (1) to guide the development of information policy; (2) because of a profound distrust of the findings of earlier [user] studies; and (3) because of the conviction that scientists in <u>this</u> discipline, in <u>this</u> association, or in <u>this</u> agency are so unique in their information-processing behavior that only a new study will suffice to guide information policy.[77]

User studies have been variously criticized. In compiling their chapter on "Information Needs and Uses in Science and Technology," Saul and Mary Herner list the following problems associated with user studies:[78]

- the diversity and ambiguity of language in discussing the techniques and terminology and results of the study,
- the lack of innovative methodology,
- the failure to build on past gains and to profit from past mistakes, and
- the frequent absence of rigorous experimental designs.

Another problem associated with user studies in science and technology is that in many of these studies it is unclear which of the two groups [engineers or scientists] was studied.

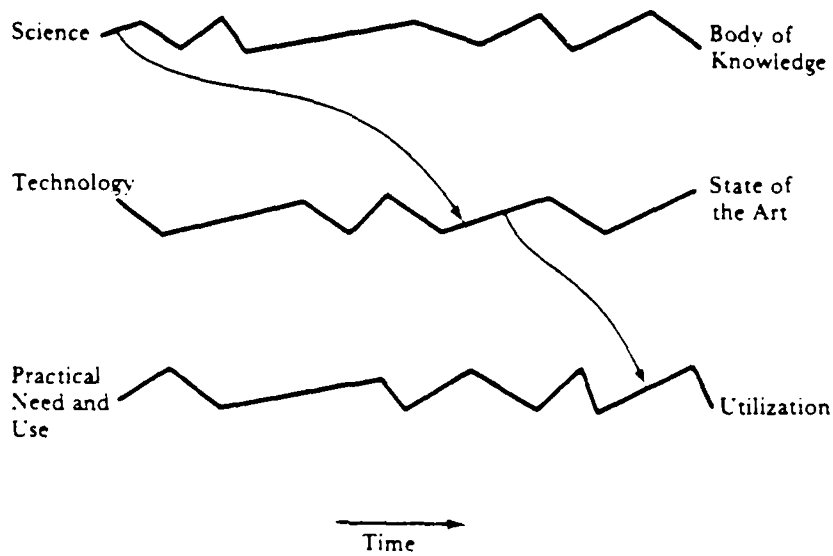
According to Allen, "the argument that scientist is a more generic term that covers both scientists and technologists merely evades the fundamental issue. The two populations are very different in their behavior, perhaps most particularly in their communication behavior."[79] Seiss, who supports Allen's position, states that "the terms engineer and scientist are not synonymous and that the difference in work environment and personal/professional goals between the engineer and scientist proves to be an important factor in determining their information-seeking practices."[80]

Distinguishing Engineers From Scientists

Engineers are not scientists. Despite certain similarities, the two groups are fundamentally different. The difference stems from two primary considerations: (1) the independent nature of science and technology and (2) the social enculturation of engineers and scientists.

The Nature of Science and Technology. The relationship between science and technology is often expressed as a continuous process or normal progression from basic research (science) through applied research (technology) to development (utilization). This relationship, which is illustrated in Figure 2, is based on two widely held assumptions: (1) that technology grows out of or is dependent upon science for its

development and that (2) there is direct (established) communication between science and technology.



Source: Managing the Flow of Technology

Figure 2. The Progression From Science Through Technology to Development as a Continuous Process

However, several years of study that attempted to trace the flow of information from science to technology have produced little empirical evidence to support the relationship.[81]

There is, however, substantial evidence that refutes the relationship. Price, in his investigation of citation patterns in both scientific and technological journals, found that scientific literature is cumulative and builds upon itself, whereas technological literature is not cumulative and does not build upon itself. Citations to previous work are fewer in technological journals and are most often the author's own work. Based on his investigation of citation patterns, Price concluded that science and technology progress

independently of one another. Technology builds upon its own prior developments and advances in a manner independent of any link with current scientific frontier and often without any necessity for an understanding of the basic science underlying it. In summarizing the differences between science and technology, Price makes the following points.[82]

- Science has a cumulating, close-knit structure; that is, new knowledge seems to flow from highly related and rather recent pieces of old knowledge, as displayed in the literature.

- This property is what distinguishes science from technology and from humanistic scholarship.

- This property accounts for many known social phenomena in science and also for its surefootedness and high rate of exponential growth.

- Technology shares with science the same high growth rate, but shows quite complementary social phenomena, particularly in its attitude to the literature.

- Technology therefore may have a similar, cumulating, close-knit structure to that of science, but of the state-of-the-art, rather than of the literature.

- Science and technology each therefore have their own separate cumulating structures.

- Since the structures are separate, only in special and traumatic cases involving the breaking of a paradigm can there be a direct flow from the research front of science to that of technology or vice versa.

- It is probable that research-front technology is strongly related only to that part of scientific knowledge that has been packed down as part of ambient learning and education, not to research-front science.

- Similarly, research-front science is related only to the ambient technological knowledge of the previous

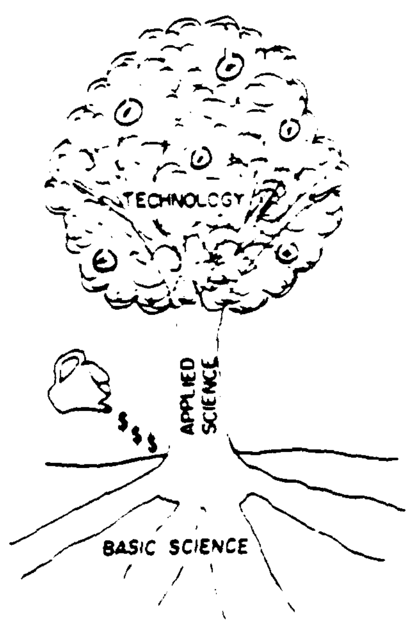
generation of students, not to the research front of the technological state-of-the-art and its innovations.

- This reciprocal relation between science and technology, involving the research front of one and the accrued archive of the other, is nevertheless sufficient to keep the two in phase in their separate growths within each otherwise independent cumulation.

- It is therefore naive to regard technology as applied science, or clinical practice as applied medical science.

- Because of this, one should beware of any claims that particular scientific research is needed for particular technological potentials, and vice versa. Both cumulations can only be supported for their own separate ends.

The single tree concept, shown below in Figure 3, is

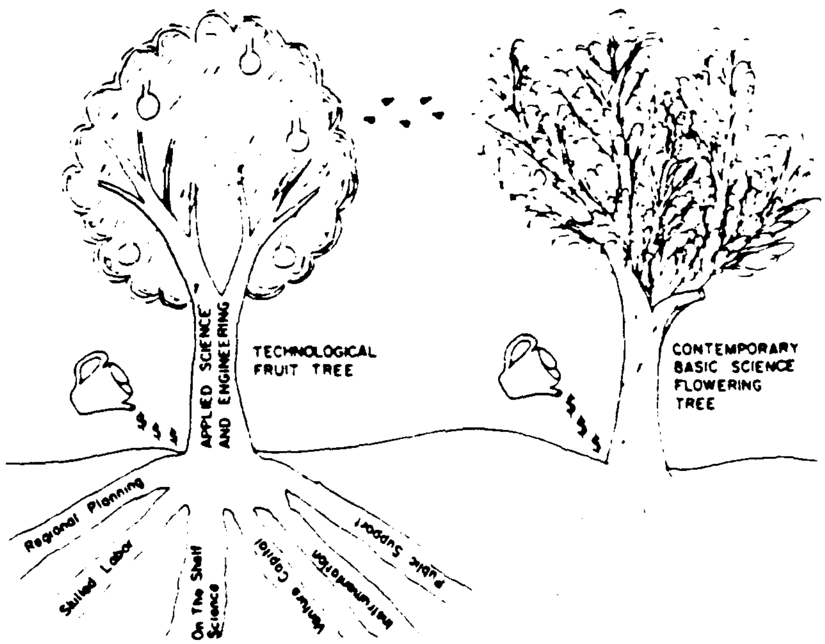


Source: <u>Lost at the Frontier</u>

Figure 3. Science and Technology as a Single Tree

often used to illustrate the relationship between science and technology as a continuous process. Shapley and Roy argue

that such a metaphor is historically inaccurate. In their case for a reorientation of American science policy, they argue that the two tree concept, which is shown in Figure 4, is a more accurate metaphor and is much more useful in developing science policy.



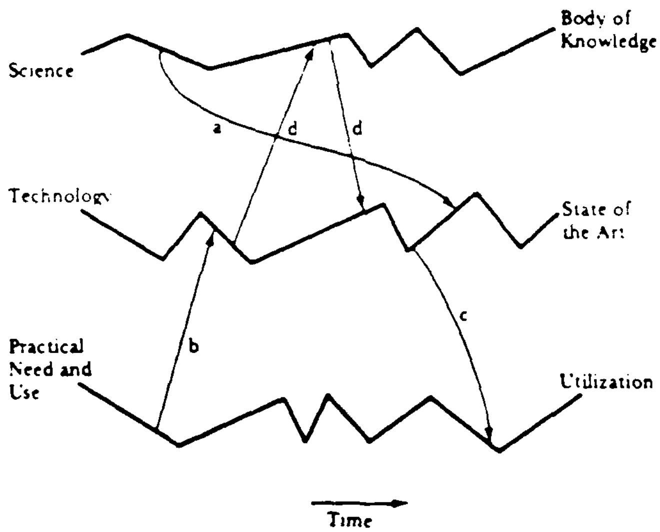
Source: Lost at the Frontier

Figure 4. Science and Technology as Separate Trees

Shapley and Roy contend that a normal progression from science to technology does not exist, nor is there direct communication between science and technology.[83] To support their position, Shapley and Roy point to the results of innovation research studies, in particular, the results of Project Hindsight. This study attempted to trace technological advancements resulting from DOD funded research back to their scientific origins and found that, while none of

the technological advancements would have been possible without basic science, the link between science and technology was extremely weak.[84]

Allen, who studied the transfer of technology and the dissemination of technological information in R&D organizations, found little evidence to support the relationship between science and technology as a continuous relationship. Allen reached two conclusions with respect to the relationship between science and technology. The relationship between science and technology, which is depicted in Figure 5, is best described as a series of interactions that are based on need rather than on a normal progression



Source: Managing the Flow of Technology

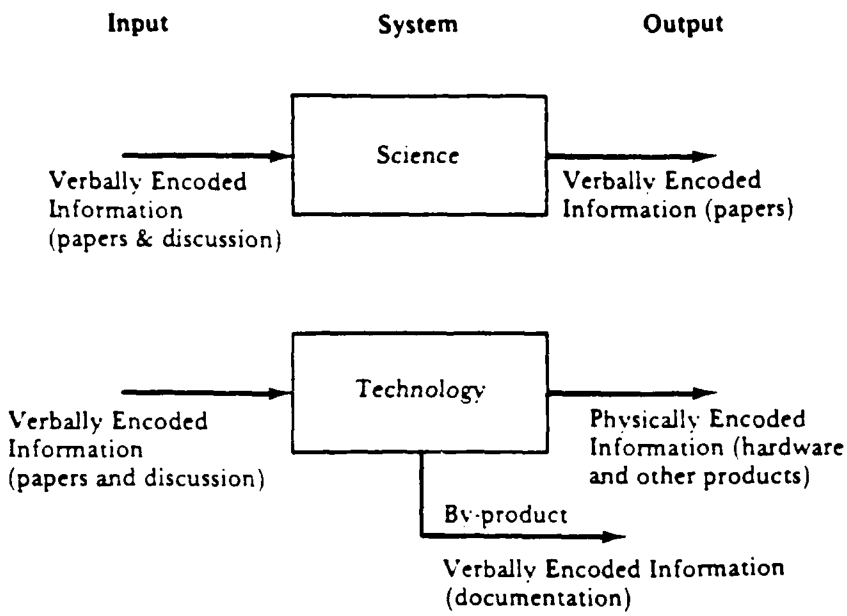
Figure 5. The Progression From Science Through Technology to Development as a Series of Interactions

According to Allen (1) the results of science do progress to technology in the sense that some sciences such as physics are more closely connected to technologies such as electronics,

but that, overall, a wide variation exists between science and technology; (2) the need for a device, technique, or scientific understanding influences technology; (3) technology, in turn, responds to a need; and (4) in doing so, may generate the need for an understanding of certain physical phenomena. A direct communication system between science and technology does not exist to the point that communication between science and technology is restricted almost completely to that which takes place through the process of education.[85]

The independent nature of science and technology and the different functions performed by engineers and scientists directly influence the flow of information in science and technology. Science and technology are ardent consumers of information. Both engineers and scientists require large quantities of information to perform their work. At this level, there is a strong similarity between the information input needs of engineers and scientists. However, the difference between engineers and scientists in terms of information processing becomes apparent upon examination of their outputs.[86]

Information processing in science and technology is depicted in Figure 6 in the form of an input-output model.



Source: Managing the Flow of Technology

Figure 6. Information Processing in Science and Technology

Scientists use information to produce information. From a system's standpoint, the input and output, which are both verbal, are compatible. The output from one stage is in a form required for the next stage. Technologists use information to produce some physical change in the world. Technologists consume information, transform it, and produce a product that is information bearing; however, the information is no longer in verbal form. Whereas scientists consume and produce information in the form of human language, engineers transform information from a verbal format to a physically encoded form. Verbal information is produced only as a by-product to document the hardware and other physical products produced.

According to Allen, there is an inherent compatibility between the inputs and outputs of the information processing system of science. Since both are in a verbal format, the output of one stage is in the format required for the next stage. The problem of supplying information to the scientist becomes a matter of collecting and organizing these outputs and making them accessible. Since science operates for the most part on the premise of free and open access to information, the problem of collecting outputs is made easier.[87]

In technology, however, there is an inherent incompatibility between inputs and outputs. Since outputs are usually in a form different from inputs, they usually cannot serve as inputs for the next stage. Further, the outputs are usually in two parts, one physically encoded and the other verbally encoded. The verbally encoded part usually cannot serve as input for the next stage because it is a by-product of the process and is itself incomplete. Those unacquainted with the development of the hardware or physical product therefore require some human intervention to supplement and interpret the information contained in the documentation.[88] Since technology operates to a large extent on the premise of restricted access to information, the problem of collecting the documentation and obtaining the necessary human intervention become difficult.

The Social Enculturation of Engineers and Scientists. In their study of the values and career orientation of engineering and science undergraduate students, Krulee and Nadler found that engineering and science students have certain aspirations in common: to better themselves and to achieve a higher socio-economic status than that of their parents. In contrast, science students place a higher value on independence and on learning for its own sake while engineering students are more concerned with success and professional preparation. Many engineering students expect their families to be more important than their careers as a source of satisfaction, but the reverse pattern is more typical for science students. Finally, science students tend to value education as an end in itself while engineering students tend to value education as a means to an end.[89]

Krulee and Nadler also determined that engineering students are less concerned than science students with what one does in a given position and more concerned with the certainty of the rewards to be obtained. Overall, engineering students place less emphasis on independence, career satisfaction, and the inherent interest their specialty holds for them, and place more value on success, family life, and avoiding a low-level job. Engineering students appear to be prepared to sacrifice some of their independence and opportunities for innovation in order to realize their primary objectives. Engineering students are more willing to accept

positions that will involve them in complex organizational responsibilities and they assume that success in such positions will depend upon practical knowledge, administrative ability, and human relation skills.[90]

In his study of engineers in industry, Ritti found marked contrast between the work goals of engineers and scientists. Ritti draws the following three conclusions from his study:[91]

- The goals of engineers in industry are very much in line with meeting schedules, developing products that will be successful in the marketplace, and helping the company expand its activities.

- While both engineers and scientists desire career development or advancement, for the engineer, advancement is tied to activities within the organization, while advancement for the scientist is dependent upon the reputation established outside of the organization.

- While publication of results and professional autonomy are clearly valued goals of the Ph.D. scientist, they are clearly the least valued goals of the baccalaureate engineer.

Allen states that the type of person who is attracted to a career in engineering is fundamentally different from the type of person who pursues a career as a scientist. Perhaps the single most important difference between the two is the level of education. Engineers are generally educated to the baccalaureate level; some have a Masters degree while some have no college degree. The research scientist is usually assumed to have a doctorate. The long, complex process of academic socialization involved in obtaining the Ph.D. is bound to result in a person who differs considerably in his/her lifeview. These differences in values and attitudes

toward work will almost certainly reflect in the behavior of the individual, especially in their use and production of information.[92]

According to Blade, engineers and scientists differ in training, values, and methods of thought. Further, Blade states that the following differences exist in their individual creative processes and in their creative products.[93]

- Scientists are concerned with discovering and explaining nature; engineers use and exploit nature.
- Scientists are searching for theories and principles; engineers seek to develop and make things.
- Scientists are seeking a result for its own ends; engineers are engaged in solving a problem for the practical operating results.
- Scientists create new unities of thought; engineers invent things and solve problems. This is a different order of creativity.

Finally, Holmfeld states that communication in engineering and science are fundamentally different. Communication patterns differ because of the fundamental differences between engineering and science and because of the social systems associated with the two disciplines. The following characteristics of the social systems as they apply to the engineer and scientist are based on Holmfeld's investigation of the communication behavior of engineers and scientists.[94]

Engineer

- contribution is [technical] knowledge used to produce end-items or products
- new and original knowledge is not a requirement
- reward is monetary or materialistic and serves as an inducement to continue to make further contributions to technical knowledge
- to seek any of the rewards that are not part of the social system of technology is quite proper and also encouraged
- the value of technical knowledge lies in its value as a commodity of indirect exchange
- exchange networks found in the social system of technology are based on end-item products, not knowledge
- strong norms against free exchange or open access to knowledge with others outside of the organization exist in the social system of technology
- if free and open access to knowledge characterizes the social system of science, restriction, security classification, and proprietary claims to knowledge characterize the social system of technology

Scientist

- contribution is new and original knowledge
- reward is social approval in the form of professional [colleague] recognition
- recognition established through publication and claim of discovery
- a well-developed communication system based on unrestricted access is imperative to recognition and claim of discovery
- since recognition and priority of discovery are critical, strong norms against any restriction to free and open communication exist in the social system of science

- to seek any of the rewards that are not part of the social system of science in return for scientific contribution is not considered proper within the social system of science
- exchange networks commonly referred to as "invisible colleges" exist in the social system of science; in these networks the commodities are knowledge and recognition[95,96]

Selected Research Findings

Studies concerned with the production, transfer, and use of *STI by engineers have been reviewed* to help further develop the conceptual framework for the study. Although not intended to be comprehensive, this material does present the general tone of the research and literature related to the information-seeking and processing behavior of engineers.

YEAR	PRINCIPAL INVESTIGATOR	SPONSOR	DESCRIPTION
1954	Saul Herner[97]	Navy Dept.	Survey of engineers & scientists at Johns Hopkins University
1970	Richard S.[98] Rosenbloom Francis W. Wolek	NSF et al.	Survey of R&D engineers and scientists in industry
1977	Thomas J.[99] Allen et al.	NASA NSF	A ten-year study of technology transfer and the dissemination of technological information in R&D organizations
1980	Jeannette M.[100] Kremer	Ph.D. Diss.	Survey of engineers in a design firm
1981	Hedvah L.[101] Shuchman	NSF	Survey of 1,300 engineers representing 14 industries
1983	Harold G.[102] Kaufman	NSF	Survey of 147 mid-career engineers in industry

Herner used personal interviews of 606 engineers and scientists at Johns Hopkins working in applied (69 percent) and pure (31 percent) areas of science and technology to determine their use of information and reference sources.

Descriptive statistics were used to analyze and interpret the findings. The significant findings of the study appear below.

- Personnel in the applied areas of science and technology obtained approximately 50 percent of their information from the formal literature compared to 75 percent for those working in the pure areas.

- Engineers in the School of Engineering obtained approximately 80 percent of their information from the formal literature while engineers working in the Applied Physics Laboratory obtained approximately 50 percent of their information from the formal literature.

- Personnel in the applied areas of science and technology considered the following five formal sources of information to be most useful:

  - advanced textbooks and monographs
  - research journals
  - research reports
  - handbooks
  - mathematical and physical tables

- Personnel in the pure areas of science and technology considered the following five formal sources of information to be most useful:

  - advanced textbooks and monographs
  - research journals
  - handbooks
  - mathematical and physical tables
  - review publications

- Engineers in the School of Engineering listed the following five sources of formal information as being most useful:

  - advanced textbooks and monographs
  - research journals
  - mathematical and physical tables
  - unclassified research reports
  - theses

- Engineers in the Applied Physics Laboratory listed the following five sources of formal information as being most useful:

  - handbooks
  - security classified technical reports
  - advanced textbooks and monographs
  - research journals
  - trade publications

- Personnel in the applied areas of science and technology considered the following five informal sources of information to be most useful:

  - personal recommendations
  - cited references
  - regular perusing
  - indexes and abstracts
  - bibliographies

- Personnel in the pure areas of science and technology considered the following five informal sources of information to be most useful:

  - consulting cited references
  - personal recommendations
  - regular perusing
  - indexes and abstracts
  - bibliographies

- Engineers in the School of Engineering listed the following five sources of informal information as being most useful:

  - consulting cited references
  - regular perusing
  - indexes and abstracts
  - bibliographies
  - personal recommendations

- Engineers in the Applied Physics Laboratory listed the following five sources of informal information as being most useful:

  - personal recommendations
  - consulting cited references
  - regular perusing
  - indexes and abstracts
  - library card catalog

- In terms of library use, 12 percent of the personnel working in the applied areas of science and technology depended mainly on the library for their published material as compared to 64 percent of the pure areas of science and technology.

- Personnel working in the pure areas of science and technology did slightly more than twice (17 percent) their reading in the library than did those personnel in the applied areas (8 percent); the engineers did the smallest amount of their reading in the library.

- Of the four major library reference services offered, 35 percent of those personnel in the pure areas of science and technology made use of these services as compared to 79 percent of those personnel working in the applied areas.

- Personnel working in the applied areas of science and technology made greatest use of the following library reference services:

    - accession/reading lists
    - bibliographies
    - guidance by library staff
    - translations

- Personnel working in the pure areas of science and technology made greatest use of the following library reference services:

    - accession/reading lists
    - guidance by library staff
    - translations
    - bibliographies

- Engineers in the School of Engineering made considerably less use of library reference services than did those in the Applied Physics Laboratory.

The study by Rosenbloom and Wolek involved 1,900 engineers and scientists in thirteen establishments of four large corporations and 1,200 members of the Institute of Electrical and Electronics Engineers (IEEE). Data were collected by means of a self-administered questionnaire that elicited descriptions of a single [critical] incident of

information transfer. Inferential statistics, including factor analysis, multiple regression, and multivariate analysis, were used to analyze and interpret the findings. The significant findings of the study are presented below.

- Engineers tend to make substantially more use of information sources within the corporation than do scientists.

- Scientists tend to use the professional (formal) literature approximately three times as much as engineers.

- There were no striking differences between engineers and scientists in terms of "recognizing" the need for information; however, scientists did report a greater number of cases in which the information they used was acquired originally as a consequence of activities directed toward general competence, rather than a specific task.

- There was no real difference between engineers and scientists and their use of interpersonal communication; however, engineers reported a greater incidence of interpersonal communication with people in other parts of their own corporation whereas scientists reported a greater incidence of interpersonal communication with individuals employed outside their own corporation.

- When using documents, engineers tend to consult corporate reports or trade publications, while scientists tend to make greater use of the professional [formal] literature.

- In the case of both engineers and scientists, the propensity to use alternative types of technical information sources is related to the purposes which will give meaning to the use of that information. Work that has a professional focus draws heavily on sources of information external to the user's organization. Conversely, work that has an operational focus seldom draws on external sources, relying heavily on information that is available within the employing organization.

- Those engineers and scientists engaged in professional work commonly emphasize the simplicity, precision, and analytical or empirical rigor of the information source. Conversely, those engineers and scientists engaged in operational work typically emphasize the value of communication with others who understand and are experienced in the same real context of work.

Allen's study is the result of a ten-year investigation of the dissemination of technological information within the R&D organization. Allen describes the study, which began as a "user study," as a system-level approach to the problem of communication in technology. Data were collected by means of a "solution development record." Descriptive statistics were used to analyze and interpret the data. The significant findings of the study are presented below.

- In terms of sources of information as an idea source, approximately 45 percent came from personal contacts.

- In terms of sources of information as input to problem-definition, approximately 63 percent came from personal contacts.

- In terms of literature use, formal literature comprised 45 percent, while informal literature (that is, unpublished reports) comprised 55 percent.

- Most frequently used formal literature sources included textbooks, followed by trade journals, followed by privately-sponsored engineering journals (for example, those published by Bell Labs).

- Approximately 50 percent of an engineer's formal literature is contained in his/her own personal work area; approximately 30 percent is obtained from a personal search of the company library while only 6 percent is obtained with the assistance of a librarian.

- The unpublished report is the single most important informal literature source; "it is the principal written vehicle for transferring information in technology."

- In terms of the unpublished report, internal reports were used first, followed by reports from other companies, followed by U.S. government technical reports.

- The unpublished report was used principally in direct problem solving and was most often obtained from a colleague or a personal file while less than 2 percent were obtained with the assistance of a librarian.

- Within R&D organizations technological gatekeepers exist; their job is to import technical information and to connect members of the organization with that information.

Kremer's study was undertaken to gain insight on how technical information flows through formal and informal channels among engineers in a design company. The population surveyed was not involved in R&D. A self-administered questionnaire based on the critical incident technique was used to collect the data. Inferential statistics were used to analyze and interpret the data. Significant findings from the study are presented below.

- In terms of information sources, handbooks were considered most important, followed by standards and specifications, followed by meeting with colleagues.

- Personal files were the most frequently consulted source for needed information.

- The reason given most frequently to search for information was problem solving; colleagues within the company were contacted first for needed information followed by colleagues outside of the company.

- Libraries were not considered to be important sources of information and were used infrequently by company engineers.

- Regardless of age and work experience, design engineers demonstrated a decided preference for internal sources of information.

- The perceived accessibility, ease of use, technical quality, and the amount of experience a design engineer has had with an information source strongly influence the selection of an information source.

- Technological gatekeepers were found to exist among design engineers; they were high technical performers and a high percentage were first line supervisors.

Shuchman's study is a broad based investigation of information transfer in engineering. Respondents represented fourteen industries and the following major disciplines: civil, electrical, mechanical, industrial, chemical and environmental, and aeronautical. Of the 1,315 respondents (39 percent response rate), 7 percent worked in R&D while 27 percent held positions in management. Seven percent or 93 respondents were aeronautical engineers. Data were collected through the use of interviews and a self-administered questionnaire. Descriptive and inferential statistics were used to analyze and interpret the data. The significant findings of the study are presented below.

- Engineers, regardless of discipline, displayed a strong preference for informal sources of information.

- Engineers rarely find all the information they need for solving technical problems in one source; the major difficulty engineers encounter in finding the information they need to do their job is identifying a specific piece of missing data and then learning who has it.

- In terms of information sources and solving technical problems, engineers first consult their personal store of technical information, followed by informal discussions with colleagues, followed by discussions with supervisors, followed by use of internal technical reports, followed by a "key" person in the organization who usually knows where the needed information may be located.

- Technical libraries and librarians are used by a small proportion of the engineering profession.

- The information needed by engineers varies somewhat from the information they produce

Information Needed	Information Produced
- basic S&T knowledge	- in-house technical data
- in-house technical data	- new methods
- physical data	- design methods
- product characteristics	- physical data
- design methods	- basic S&T knowledge

- In general, engineers do not regard information technology as an important adjunct to the process of producing, transferring, and using information.

- While gatekeepers appear to exist across the broad range of engineering disciplines, their function and and significance is not uniform; considering the totality of engineering, gatekeepers account for only a small part of the information transfer process.

Kaufman's study is concerned with the factors relating to the use of technical information in engineering problem solving. Data were collected from 147 engineers in six organizations by means of a self-administered questionnaire and the critical incident technique. Inferential statistics, including the use of factor and path analysis, were used to

analyze and interpret the data. Significant findings for the study are presented below.

- o In terms of information sources, engineers consulted their personal collections first, followed by colleagues, followed by literature sources.

- o In terms of formal information sources used for technical problem solving, engineers used technical reports, followed by books and monographs, followed by technical handbooks.

- o Most sources of information were found primarily through an intentional search of written information followed by personal knowledge, followed by asking someone.

- o The criteria used in selecting all information sources are listed below in descending order of frequency.

  - accessibility
  - familiarity or experience
  - technical quality
  - relevance
  - comprehensiveness
  - easy to use
  - expense

- o The various information sources were used by engineers for specific purposes.

  - librarians/information specialists were primarily utilized to find leads to information sources

  - online computer searches were used primarily to define the problem

  - literature was used primarily to learn techniques applicable to dealing with the problem

  - personal experience was used primarily to find solutions to the problem

- o The criteria used in selecting the most useful information sources are listed below in descending order of frequency.

  - technical quality or reliability
  - relevance
  - accessibility

- familiarity or experience
- comprehensiveness
- easy to use
- expense

o In terms of the effectiveness, efficiency, and usefulness of the various information sources, personal experience was rated as the most effective in accomplishing the purpose for which it was used; librarians/information specialists received the lowest rating for efficiency and effectiveness.

o Most engineers used several different types of information sources in problem solving; however, engineers do depend on their personal experience more often than on any single specific information source.

Discussion

Engineers are not scientists. The differences between the two groups stem from the fundamental differences between science and technology and the social enculturation of engineers and scientists. These differences prove to be important factors in determining the information-seeking and processing behavior of the two groups, which are quite different. Further, the fundamental differences in information-seeking and processing, by implication, mean that an STI system designed for scientists would be somewhat less than optimum for use by engineers. Yet it is precisely this approach, the assumption that science and technology are similar and so are the information-seeking and processing behavior of engineers and scientists, that most often guides the development of STI systems. Herner, who is quoted by

Allen, makes the following case for consideration of user differences when developing STI systems.[103]

> Perhaps the most important and least considered factor in the design of information storage and retrieval systems is the user of such systems. Regardless of what other parameters are considered in the development of a storage and retrieval mechanism, it is necessary to consider its potential use and mode of use by the persons or groups of persons for whom it is intended. It is necessary either to fashion the system to suit the user's needs, habits, and preferences or to fashion the user to meet the needs, habits, and preferences of the system. Both approaches are possible, but the second one, involving education and re-education of the user, is evolutionary and futuristic.

As Holmfeld has previously demonstrated, the difference in the communication behavior of engineers and scientists can be traced to the social systems associated with the two disciplines. Unlike scientists, the vast majority of engineers are employed by organizations having well-defined missions such as making a profit. This organizational identification does two things to the engineer. First, unlike the scientist, the engineer is required to work only on problems that are of interest to his employer. Second, unlike the scientist, the engineer must often refrain from early disclosure of the research results in order to maintain the organization's competitive advantage over the competition. Both conditions are in sharp contrast to the social system of science in (1) that the scientist is free to choose the problem to be investigated and that the community of scientists will judge the relative importance of the area of investigation and (2) that the full and complete results of

the investigation be freely communicated to the entire scientific community. By not adhering to these two norms, the formation of anything resembling the invisible college found in science is practically non-existent in technology. On the other hand, it is precisely these conditions that contribute to the creation of gatekeepers in technology.

Not adhering to these two norms also affects how engineers communicate. While scientists are free to openly communicate, engineers are inhibited from open communication with colleagues in different organizations for fear that proprietary information, vital to the organization's position in the marketplace, will be lost. Further, while scientists are encouraged and expected to openly communicate in the literature of science, engineers are not encouraged and are often prohibited from openly communicating in the literature of technology because information is often considered proprietary and must be protected. It is, however, published within the organization in the form of a technical report and thus becomes an important source of information for the engineer just as the scientific journal is an important source of information for the scientist. Engineers and scientists also differ in the extent to which they use oral and written channels of communication. Both make substantial use of personal contacts. However, the persons contacted by both groups are quite different and they are contacted for very different reasons. The literature used by engineers and

scientists is quite different. Scientists spend considerably more time in the literature than do engineers while engineers spend considerably more time in personal contacts than they do reading the literature.

In terms of normalized findings, engineers tend to seek information when information is needed to solve a problem. In doing so, they tend to seek information from a variety of sources, beginning first with their personal store of information followed by discussions with colleagues with in the organization. They tend not to be heavy users of libraries. Other than technical reports, handbooks, and standards, they tend not to be heavy users of the formal literature.

There is little evidence to support the existence of invisible colleges in engineering. There is, however, considerable evidence to support the existence of gatekeepers, whose function is apparently not uniform throughout all engineering disciplines. While the gatekeeper is an important source of information in solving technical problems, it appears that the gatekeeper accounts for only a small part of the information transfer process.

Certain criteria are used by engineers in selecting information sources. More times than not, an information source is selected because it is accessible or familiar to an engineer. Certain information sources are judged to be more effective and efficient for accomplishing certain purposes.

The criteria used to select a particular information source is different from the criteria attached to the usefulness of an information source. Furthermore, it appears that engineers make little use of information technology for the production, transfer, and use of STI.

Only one of the studies concerned with the production, transfer, and use of STI by engineers included aeronautical engineers in the sample population. The results of that study indicate that aeronautical engineers, like other engineers, are users of technical reports. However, because of sample size and selection, the results cannot be generalized to the entire population of aeronautical engineers and scientists. Furthermore, as with all of the studies reviewed, there is no way to determine whether government or non-government technical reports are being used. Therefore, it seems both reasonable and prudent to conduct an exploratory study designed to investigate the role of the U.S. government technical report in aeronautics.

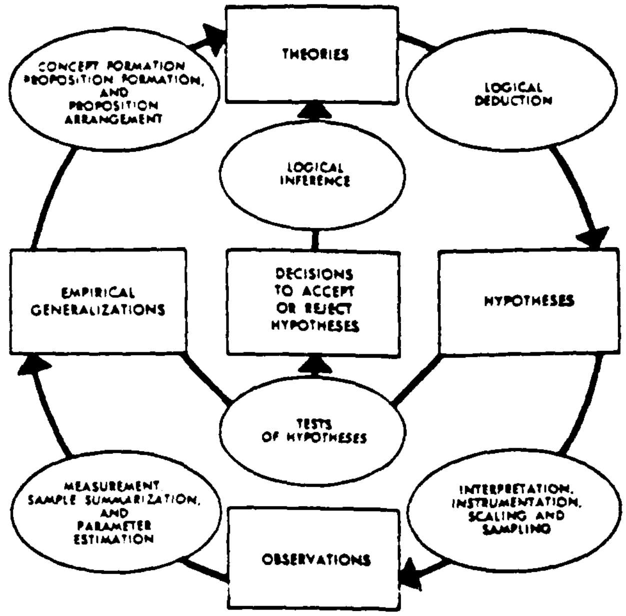
Much more knowledge and understanding concerning how engineers produce, transfer, and use STI is needed. This information could be useful in developing new STI systems and for evaluating existing ones. This information could also be used to develop and assess STI policy and in developing strategies designed to increase U.S. industrial innovation, productivity, and competitiveness. Research related to the

production, transfer, and use of STI by engineers might include the following questions:

- To what extent is the information-seeking and processing behavior of engineers homogeneous?
- To what extent do certain structural and institutional factors affect or influence the information-seeking and processing behavior of engineers?
- To what extent can these structural and institutional factors predict the information-seeking and processing behavior of engineers?
- To what extent do certain factors such as accessibility and familiarity affect the selection of a particular information source or product?
- To what extent is the production and use of the U.S. government technical report affected or influenced by these factors?

THEORETICAL FRAMEWORK

In the traditional model of science, theory, and research are inseparable. The traditional model of science, which is illustrated in Figure 7 using Wallace's model,[104] includes theories, hypotheses, observations, and empirical generalizations.



Note: Informational components are shown in rectangles; methodological controls are shown in ovals; information transformations are shown by arrows.

Source: The Logic of Science in Sociology

Figure 7. The Principal Informational Components, Methodological Controls, and Information Transformations of the Scientific Process

According to this model, theory generates hypotheses, hypotheses suggest observations, observations produce generalizations, and generalizations result in modifications of the theory. The modified theory then suggests somewhat modified hypotheses and a new set of observations, which produce somewhat revised generalizations, further modifying the theory.[105]

Theoretical Development

According to this model, a researcher begins with an interest in some aspect of the real world. In this particular

study, the interest is in the behavior of aeronautical engineers and scientists with respect to the production, transfer, and use of STI. As with most aspects of research, interest in the behavior of engineers and scientists with respect to information is not a wholly new area of research, thus this study will utilize and build upon the cumulative body of relative knowledge. In a theoretical sense, this study will build upon certain empirical generalizations drawn from previous research. According to theory and research, there are fundamental differences between science and technology and between engineers and scientists. These differences bring about fundamentally dissimilar behavior with respect to how engineers and scientists produce, transfer, and use STI. This study will add to the cumulative body of relative knowledge by exploring the relationship between certain factors and the production, transfer, and use of STI by aeronautical engineers and scientists.

Conceptual Framework

The conceptual framework for the study, which is shown in Figure 8, is an extension of Mick's model for general information seeking.[106]

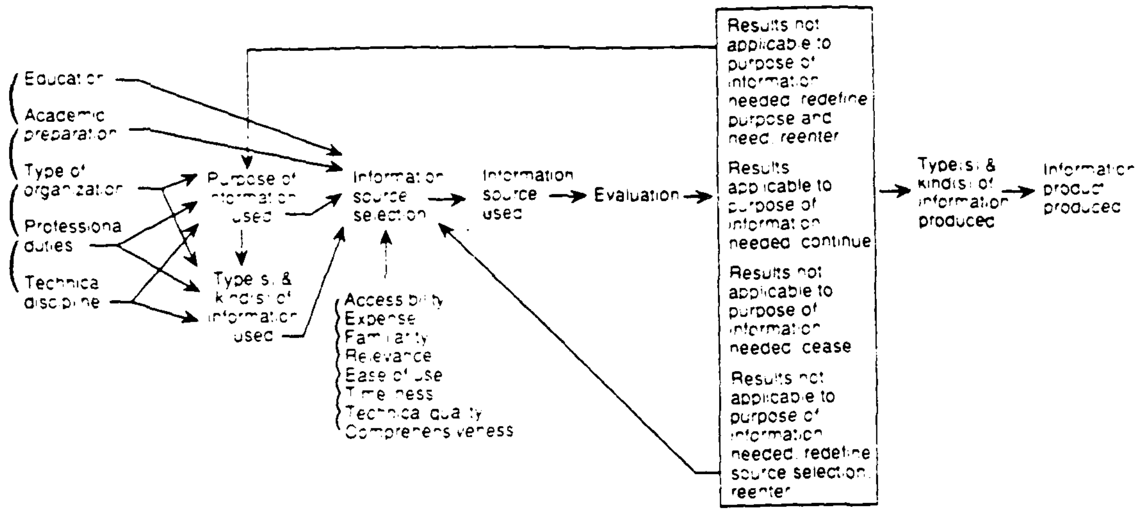


Figure 8. A Conceptual Model for the Production, Transfer, and Use of Scientific and Technical Information by U.S. Aeronautical Engineers and Scientists

The conceptual model assumes that, not withstanding individual differences, there is an internal, consistent logic which governs the information-seeking and processing behavior of aeronautical engineers and scientists. That logic is the product of several interacting structural and institutional factors, the purpose [task] for which the information is used, and the perceived utility of various information sources as affected by certain criteria. The model is shown as a flowchart consisting of several functions and actions including an evaluation function and a reinforcement function that provides feedback.

The proposed study is exploratory in nature. Therefore, no attempt will be made to investigate or validate the entire

model. Instead, the study will focus on that part of the model that is identified below in Figure 9. While data will be collected on production, transfer, and use of STI by aeronautical engineers and scientists, only that portion of the model so identified will be investigated.

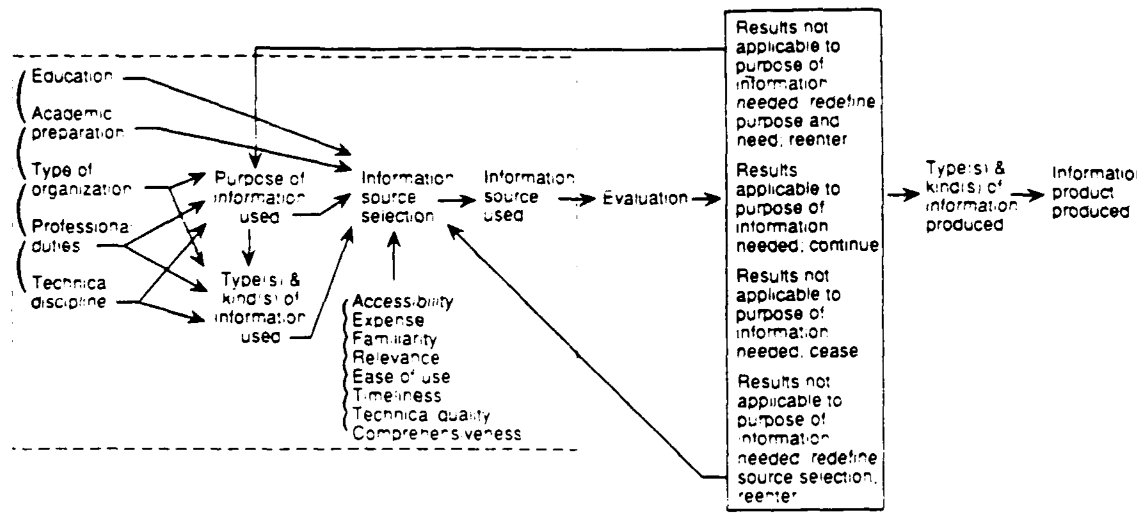


Figure 9. The Portion of the Conceptual Model to be Investigated in the Proposed Study

Key Variables

The central variables for the proposed study describe the functions associated with the production, transfer, and use of STI by aeronautical engineers and scientists. Two types of variables, exogenous and endogenous, are distinguished. There are two sets of exogenous variables. The first are the structural and institutional variables, which include education, academic preparation, type of organization, professional duties, and technical discipline. The second

are the information source selection variables, which include accessibility, expense, familiarity, relevance, ease of use, timeliness, technical quality, and comprehensiveness. Operational definitions are provided first for the structural and institutional (exogenous) variables and second for the information source selection (exogenous) variables. The definitions given for the information source selection variables are those used by Allen and Kaufman in their studies.

Structural and Institutional Variables

- Education *
  - less than a Bachelor's degree
  - Bachelor's degree in ______________
  - Master's degree in ______________
  - Doctorate in ______________________
- Academic Preparation *
  - Engineer
  - Scientist
  - Other ______________
- Years of Professional Work Experience
  - ______ years
- Type of Organization (current) *
  - Academic
  - Government (NASA only)
  - Government (DOD only)
  - Government (all other)
  - Industry
  - Not-For-Profit
  - Other ______________

---

* shown in conceptual model

- Professional Duties *

  - Research
  - Teaching/Academic (may include research)
  - Private Consultant
  - Design/Development
  - Manufacturing/Production
  - Marketing/Sales
  - Service/Maintenance
  - Administrative/Management (for profit sector)
  - Administrative/Management (not-for-profit sector)
  - Other ________________

- AIAA Interest Group

  - Aerospace Science
  - Aircraft Systems
  - Structures, Design, and Test
  - Propulsion and Energy
  - Aerospace and Information Systems
  - Administrative/Management
  - Other ________________

- Technical Discipline *

  - Aeronautics
  - Astronautics
  - Chemistry and Materials
  - Communications
  - Computational Fluid Dynamics
  - Engineering (excluding aero and astronautical)
  - Fluid Mechanics
  - Geosciences
  - Life Sciences
  - Math and Computer Science
  - Physics
  - Psychology
  - Space Sciences
  - Other ______________

Information Source Selection Variables *

- Accessibility - the ease of getting to the information source

- Expense (cost) - the expense in either time, effort, or money in comparison to another information source

---

* shown in conceptual model

- Familiarity (experience) - prior knowledge or previous use of an information source

- Relevance - the expectation that a high percentage of the information retrieved from the source would be useful

- Ease of Use - the ease of understanding, comprehending, or utilizing the information source

- Timeliness - the expectation that the information can be obtained in the time in which it is needed

- Technical Quality (reliability) - the expectation that the information source would be the best in terms of quality

- Comprehensiveness - the expectation that the information source would provide broad coverage of the available knowledge

The proposed study has three endogenous variables. They include the purpose of information used, the type(s) and kind(s) of information used (and produced), and the information source/product used (and produced). Operational definitions are provided below for each variable.

- Purpose of Information Used

  - Science

    - Scientific investigation of physical phenomena
    - Formulation or testing of S&T theories, concepts, or models

  - Technology

    - Formulation, development, and investigation of new approaches to technical objectives
    - Combination and integration of generally available designs and components into desired products, processes, and test procedures
    - Refinement of existing products, processes, or test procedures

- General

  - Planning, budgeting, and managing research
  - Professional development, current awareness, or general interest
  - Other (please specify) ________________

o Type(s) or Kind(s) of Information Used (or Produced)

- Science

  - Basic S&T information
  - Physical data

- Technology

  - In-house technical data
  - Product and performance characteristics
  - Design procedures and methods
  - Other (please specify) ______________

- General

  - Economic and business information
  - Other (please specify) ______________

o Information Sources and Products

- Informal information sources

  - Personal store of information
  - Colleague
  - Supervisor
  - "Key" person inside the organization
  - "Key" person outside of the organization
  - Consultant
  - Vendor
  - Librarian or information specialist
  - Other (please specify) ________________

- Formal information products

  - Textbooks and monographs
  - Handbooks, standards, codes of practice
  - Government technical reports
  - Industrial technical reports
  - Patent specifications
  - Review journals
  - Professional journals
  - Trade journals

- Conference/meeting papers
- Dissertations/theses
- Catalogs
- Numeric databases
- Bibliographic databases
- Abstracting and announcement publications
- Bibliographies
- Current awareness services
- Directories
- Yearbooks
- Dictionaries
- Encyclopedias
- Other (please specify) ____________________

Hypotheses

The conventional wisdom, as determined by the review of related research and literature, indicates that engineers and scientists exhibit separate and distinct information-seeking and processing behavior. Further, each group appears to be homogenous in terms of their information-seeking and processing behavior. That is, regardless of discipline, structural and institutional factors such as education, academic preparation, type of organization, professional duties, and technical duties do not influence, alter, or affect information-seeking and processing behavior. For the purposes of this study, it is assumed that a relationship exists between certain structural and institutional factors and the information-seeking and processing behavior of aeronautical engineers and scientists. Further, given the multidisciplinary nature of aeronautics, it is assumed that aeronautical engineers and scientists are heterogenous in terms of their information-seeking and processing behavior. The following hypotheses are based on these assumptions.

1. Aeronautical engineers and scientists having advanced degrees are more likely to use scientific information, to select a "key" individual outside of the organization as an informal information source, and to select professional journals as a formal information product than are aeronautical engineers and scientists having less formal education.

2. Aeronautical engineers are more likely to use technology information, to select a "key" individual inside of the organization as an informal information source, and to select industrial and U.S. government technical reports as a formal information product than are aeronautical scientists.

3. Aeronautical engineers and scientists working in industry and government are more likely to use technology information, to select a "key" individual inside of the organization as a informal information source, and to select industrial and government technical reports as a formal information product than are aeronautical engineers and scientists in academia.

4. Aeronautical engineers and scientists performing professional research and teaching/academic duties are more likely to use scientific information, to select a "key" individual outside of the organization as an informal information source, and to select professional journals as a formal information product than are aeronautical engineers and scientists performing professional duties that are technical and managerial.

5. Aeronautical engineers and scientists working in scientific disciplines are more likely to use scientific information, to select a "key" individual outside of the organization as an informal information source, and to select professional journals as a formal information product than are aeronautical engineers and scientists working in technology disciplines.

In addition to certain structural and institutional factors, the related research and literature indicates that the selection of information sources and products is influenced or affected by certain source selection criteria.

For purposes of this study, it is assumed that the source selection criteria factors operate independently of the structural and institutional factors. Further, it is assumed that aeronautical engineers and scientists are homogeneous in terms of source selection.

6. Aeronautical engineers and scientists are more likely to select (use) an information source or product which is either accessible or familiar to them than they are all other information source selection criteria.

Research Methodology

Saracevic and Wood state that surveys, observations, record analysis, and experimentation are the research methodologies most often used with user studies.[107] Of these methods, survey research in the form of a self-administered questionnaire will be used for this study. Specifically, Dillman's Total Design Method (TDM) for mail surveys will be utilized.[108]

There are several reasons for choosing survey research over the other possible methodologies. First, there are specific limitations associated with each research method not selected. Observation was discounted because of the time and expense required and because access to the various aeronautical organizations and installations could not be obtained. Record analysis could not be used because no known primary or secondary source(s) or records were found that could be analyzed. Experimentation was considered to be inappropriate because of the purpose and nature of the study.

Second, survey research was selected because of the ability of this methodology to gather data on a population that is too large to observe directly. By distributing a self-administered questionnaire to a sample chosen at random, a researcher can discover the relative incidence, distribution, and interrelationship between variables. Furthermore, the use of a questionnaire will permit the data to be obtained and manipulated in a uniform manner.

Mail surveys typically elicit low response (return) rates. Dillman claims, however, that with the use of his TDM, a researcher can expect to achieve results that may be comparable in quantity and quality to those obtained through face-to-face interviews at a much lower cost. Dillman offers the following description of the TDM.[109]

> The total design method consists of two parts. The first is to identify each aspect of the survey process that may affect either the quality or quantity of response and to shape each of them in such a way that the best possible responses are obtained. The second is to organize the survey efforts so that the design intentions are carried out in complete detail. The first step is guided by a theoretical view of why people respond to questionnaires. It provides the rationale for deciding how each aspect, even the seemingly minute ones, should be shaped. The second step is guided by an administrative plan, the purpose of which is to ensure implementation of the survey in accordance with design intentions.

Using the TDM, the average response rate for general public surveys is approximately 70 percent, compared with 77 percent for specialized ones. The 10-12 page questionnaire, which is the one most typically used, has an average response

rate of 76 percent with an overall item nonresponse rate of 3-4 percent of the returned questionnaires.[110] Such response and completion rates help overcome a major criticism of survey (questionnaire) research.

The critical incident technique will be used as the unit of analysis for the study.[111] The use of this technique will increase the reliability and validity of the study as this technique has been used successfully in several previous studies regarding information use and seeking behavior of engineers. According to Lancaster,

> The theory behind the critical incident technique is that it is much easier for people to recall accurately what they did on one particular occasion than it is for them to remember what they do "in general." Usually they will remember most clearly the latest incident of a particular type: this latest event becomes the "critical incident."[112]

Four assumptions are made regarding the use of the critical incident technique with this study. They are (1) that the respondent's description of the incident is valid; (2) that they can and will select the "most recent incident" without bias; (3) that their patterns of production, transfer, and use do not fluctuate significantly over moderate periods of time; and (4) that the non-respondents will not be significantly different from the respondents.

Research Design

There is no practical way to identify all of the aeronautical engineers and scientists in the U.S. For this reason, the population for this study has been identified as

the members of the American Institute of Aeronautics and Astronautics (AIAA). The AIAA is the largest American technical society devoted to engineering and science in the fields of aeronautics and astronautics. The sampling frame will consist of all aeronautical engineers and scientists who are AIAA members; who live in the U.S.; and who are employed in either academia, government, or industry. The sampling frame will be compiled from the AIAA National Membership Profile, Analysis of Employment printout as of January 1989.

A stratified random probability sample will be used for the study. Probability sampling, which assumes that each member of the sample frame has a known probability of being included in the sample, will yield a representative sampling plan. Probability sampling will make it possible to estimate the extent to which the findings based on the sample are likely to differ from what would have been found by studying the entire population of aeronautical engineers and scientists. With probability sampling, it is possible to specify the sample size that is needed to guarantee that the sample findings do not differ by more than a specified amount from those that a study of the entire population would yield. A stratified random sample will be used in this study because of the varying sizes of the three employment groups and because of the likelihood that the use of a simple random sample would result in too few academic and government AIAA members being included in the survey. Further,

stratification dramatically increases the reliability and confidence obtainable from survey data.[113]

Questionnaire Development

The questions to be included in the survey will be developed based on the study hypotheses and the conceptual model for the production, transfer, and use of STI by aeronautical engineers and scientists. Questions used in previous studies on information use and seeking behavior of engineers will be reviewed for inclusion in the instrument. The types of questions to be included in the instrument will be multiple choice, ranking, and open ended. Nominal, ordinal, and interval scales will be used to record the data. To answer most questions, respondents will have to circle a code number or insert a number in a blank. The number of open ended questions will be held to a minimum and will be used to determine the extent to which there may be discontinuity between the Federal systems which acquire, process, announce, and distribute STI to the aeronautics community and the aeronautical engineers and scientists to whom the STI is directed.

The survey instrument will be pre-coded to simplify data reduction. The data will be analyzed using the Statistical Package for the Social Sciences-X (SPSS-X). The survey will be pre-tested using three groups of twenty five aeronautical engineers and scientists at the NASA Ames Research Center, the McDonnell Douglas Corporation, and the University of

Michigan to determine the amount of time required to complete the survey, to see if the instructions are clear, and to discover any questions that may need modification because of wording or misinterpretation.

Data Analysis

Both descriptive and inferential statistics will be used to analyze and present the data. Descriptive statistics such as graphs, measures of central tendency, frequency distributions, and variability will be used. The chi-square test and Spearman's rho at the 0.05 level of statistical significance will be used as the non-parametric tests for relationships between paired variables.

Path analysis is the inferential statistic that will be used to test the relationships that are assumed to exist between the various factors identified in the conceptual model. Path analysis is similar to other multivariate methods such as multiple regression, discriminant analysis, and factor analysis. The primary difference between path analysis and other multivariate methods is in its purpose. Path analysis is used solely to test theories about hypothesized causal links between variables.[114]

Path analysis consists of three steps. The first step involves the formation of a theory that links the factors (variables) being studied. In the case of this study, it is theorized that certain structural and institutional factors are linked to information purpose, use, and source/product

selection. Further, information source/product selection is also linked to certain source selection criteria. After theory has been formulated,the next step is to select or develop measures for the factors that are specified by the theory. This step is important because path analysis will yield invalid results if the measures are not valid representations of the factors. The third step in path analysis is to estimate the equations that show the strength of relationships between each pair of factors that are causally linked in the theory. Finally, the resulting statistics must be interpreted to determine if the results support or disconfirm the theory.

ORGANIZATION OF THE STUDY

The study will be divided into seven chapters. Chapter 1 will contain the introduction, the statement of the problem, the theoretical framework, and the organization of the study. There will be two related literature chapters. Chapter 2 will be concerned with the history and development of technical report literature. Chapter 3 will be concerned with information production, transfer, and use in engineering. The research methodology makes up Chapter 4. The findings, presentation, and analysis of the data will appear in Chapters 5 and 6. The conclusions, recommendations, and implications for further research will be included in Chapter 7. Form and Style: Theses, Reports, and Term Papers is the style manual used to document the results of this study.[115]

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[2] <u>1988 U.S. Industrial Outlook</u>, 39-10.

[3] David C. Mowery. "Federal Funding of R&D in Transportation: The Case of Aviation." Paper commissioned for a workshop on <u>The Federal Role in Research and Development</u>, November 21-22, 1985, held in Washington, DC and sponsored by the National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 13.

[4] Deborah Shapley and Rustom Roy. <u>Lost at the Frontier: U.S. Science and Technology Policy Adrift</u>. (Philadelphia: ISI Press, 1985), 85.

[5] Vannevar Bush. <u>Science: The Endless Frontier</u>. (Washington, DC: Government Printing Office, 1945).

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